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SIMULATOR FOR OBTAINING MOVEMENTS WITHIN SIX DEGREES OF FREEDOM

Herbert Kruppik

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SIMULATOR FOR OBTAINING MOVEMENTS WITHIN SIX DEGREES OF FREEDOM

Herbert Kruppik

This invention concerns a simulator for obtaining movements within six degrees of freedom, especially for a vehicle, freely movable in space. /1*

Such simulators have already become known in various types of construction. The following arrangements according to German patents Nos. 963 491, 1 026 633, and 1 033 524 and also U. S. patents Nos. 1 825 462, 2 711 594, and 2 885 792 should be especially mentioned here. All these flight simulators with six degrees of freedom show, inasmuch as they are of conventional construction, that the three necessary translational movements are designed as sliding movements. If these known simulators are among the so-called unconventional construction forms, then they need additional construction elements in order to be capable of three rotational and three translational movements. But all these known simulator constructions have considerable disadvantages. With the conventional construction forms, it is of importance, that considerable alterations of the equipment are necessary, if some degrees of freedom are supposed to be left out while carrying out a simulation program. Furthermore, visibility is partially not good, since the piece of equipment already makes too large a construction necessary, in order to be of the required rigidity. This rigidity is quite difficult to achieve with this kind of equipment. A further disadvantage is that the mass to be accelerated, at least partially, is too large. Also, it is often difficult to install the drive shaft and to mount the power lines, measurement lines, and other supply lines. These forms of equipment construction need servicing. Added to this is the great difficulty in the manufacture, /2
considering the precision required. Moreover the clearance of the bearings is greater and the mass displacement has detrimental consequences for the drive.

Also the unconventional heretofore known construction forms are too large. It is especially disadvantageous here, that it is hardly possible to leave out degrees of freedom during the simulation, and that steering, in part, is difficult. If one drive fails the whole system can hardly function any longer.

It is the goal of this invention to eliminate all these disadvantages in a simple, safe, and reliable manner. This is accomplished in such a way that in a simulator for obtaining movements with six degrees of freedom, parallel crank gears, whose rotational axes can be singly started or stopped,

*Numbers given in the margin indicate pagination in original foreign text.

are connected with a test cabin in such a way, that at the most, a translational movement of the test cabin results, but all other movements remain rotational and the simulation program is only varied through a change in the gear ratio.

Now, the leaving out of degrees of freedom does not involve any longer radical changes in the whole construction of the simulator. The drive shaft mechanisms which trigger the respective degree of freedom are to be determined, while the propulsion means are then eliminated. Also, visibility is greatly improved through this invention, because in moving the turret or the cockpit, no construction parts of the movement system obstruct visibility. Aside from the one translational movement in the x-axis, the measures taken by this invention make all the rest of the degrees of freedom possible through rotational movements, because in simulators, and especially in flight simulators with six degrees of freedom small ways and angles are completely /3 sufficient.

In a further advantageous construction form of the invention it is provided that the two parallel crank gears, which are vertical to each other, are joined to a double crank gear and/or a parallel double crank gear for the accomplishment of only rotational movements in all six degrees of freedom. By this measure of the invention the equipment has been freed from all slide motion guides, which are always expensive and related with loss of effectiveness. Only rotary bearings are used. This results not only in a simple and inexpensive possibility of construction, but it also results in an almost clearance-free and exact positioning. It also is important that, contrary to the apparatus with slide motion guides, the mass itself is not displaced during movement.

In a further development of the invention it is proposed to provide a self-contained construction unit with its own propulsion, for each degree of freedom. This means that simulation movements in the direction of the y- and z-axis, can be accomplished without correction. The small deviations from the straight line, during movement in the y- and z-direction, if necessary, can be eliminated by a correction in the x-direction. If one drive fails, the rest of the drive shafts remain capable of functioning.

Further, it has proven to be advantageous that the great crank of the double crank gear, and the small crank, which is formed as an eccentric, can turn at the same time in a fixed gear ratio to each other, and that the gear elements of the parallel crank gear linearlly are infinitely variable The infinite variability of the torque to the center of gravity of the /4 turret heretofore was only possible by using a computer. Following the arrangement, as specified in the invention, such a machine is no longer necessary for this purpose.

In an especially advantageous application of the invention, an angular freely-swinging platform is connected to the parallel crank gear for the movement of the system in the y-axis or with the parallel crank gear for the system movement in the z-axis. This measure results in optimal conditions for visibility.

It is further proposed to equip the angular platform, for instance, with means for the interchangeable mounting of turrets of various sizes and forms of construction, or of other test objects. The interchangeability of the objects is greatly helped by the easy access, because of the freely swinging arrangement of the angular platform.

Further details and advantages of the invention are explained in the following description of two model constructions, as well as in the drawings.

Figure 1 shows a view of a model of the invention in the representation of the operating system 1.

Figure 2 shows the partially cut view of a model of the invention, in conformity with Figure 1, with a special view of the drive shaft.

Figure 3 shows the schematic representation of the model as in Figure 1 with the possibility of four systems of movement, as well as their mounting.

Figure 4 shows the schematic representation of the second model form, with the possibility of four systems of movement, as well as their mounting.

Figure 5 shows the schematic representation of the movement phases of the /5
parallelogram system of the simulator during the infinite variation of the distances of the y- or z-axis from the center of gravity S of the turret.

The example of the simulator model, shown in Figures 1 and 2 is in a position to carry out, rotationally, the system movements 1, shown in Figures 3 and 4, according to the degree of freedom ϕ, 2 according to ψ or ϑ', 3 according to ϑ or ψ, 4 according to the degree of freedom for the z- or y-axis, respectively, and 5 for the y- or z-axis, while the system movement 6 according to the degree of freedom for the y-axis takes place translationally. In this model example, therefore, only one sliding movement is necessary for the simulation, whereas all others are turning movements. The construction of the simulator consists of the following:

In a stand 10, which is movable in a slide guide 11 in the direction of the x-axis, rests a large universal joint 12, which at the same time receives a torsion- and bending-rigid, horizontally placed arm 13 and the horizontally placed parallel crank 14. At the other end of the arm 13 there is a small universal joint 15. The rods 16 connect flexibly the small universal joint 15 and the parallel crank 14. The universal joint 15 at the same time serves as a support for the supporting frame 17 of a plate 18. An angular platform 19 is pivotally mounted on this plate 18. On the platform 19 are the means for fastening and holding 20 for a turret 21. The parallel crank 22 is represented by the angular bend of the plate 18. On the large universal joint 12 rests the parallel crank 23. The rods 24 connect parallel crank 22 and 23 flexibly with each other. In this way the arrangement of the arm 13 with the parallel crank 14, with the small universal joint 15, with the rods /6 16 and the arrangement of the arm 13 with the parallel crank 22, with the parallel crank 23 with the rods 24, form two parallelograms, vertical to each other.

These two parallelograms are the basic principle of this simulator construction. These parallelograms, in respect to the technology of gears, represent two parallel crank gears 13, 14, 15, and 16, and 13, 22, 23, and 24. Each of these parallel cranks is capable of triggering the movements for two degrees of freedom, once for the way by torsional movement around the two fixed points and the other for the angle by rotating one fixed point around the other fixed point.

Through the two parallelograms 13, 14, 15, and 16, and 13, 22, 23, and 24 the movements for the degrees of freedom ϑ, ψ, y and z are reached. In their sequence they are dependent on the chosen system of movement (Fig. 3). The drive shaft 25 directly steers the movement of the stand 10 and the drive shaft 26, the one of the angular platform 19, while the movement of the large universal joint 12, the arm 13, the rods 16 and 24 are steered through the drive shafts 27, 28, 29, and 30 by means of intermediate elements 31, 14, and 23. The large universal joint 12, as is shown in Figure 2, can be steered directly through drive shaft 27 or, for instance, in an hydraulic construction by way of intermediate elements.

Figure 4 shows the possibilities of movement systems and their construction in a second model of the invented simulator. Instead of the stand 10, which runs in a slide 11, this model has a double crank gear 32 and/or a parallel double crank gear 33 and 34. The large universal joint 12 is placed in the large crank 32 or in the rods 35, of one of these gears. The further construction corresponds, in principle, to the arrangement of the first model.

This simulator construction again is characterized by the two, mutually /7 perpendicular parallelograms, formed by the parallel crank gears 13, 14, 15, and 16, and 13, 22, 23, and 24. Added to these gears is now a double crank gear 32 and/or a parallel double crank gear 33 and 34. In this way, straight line movements are replaced by rotational movements and all sliding movements are avoided. The deviations from a straight line, as tests have shown, extend only to a few tenths of a millimeter.

Since the principle of both gears is the same, it is only necessary to describe the double crank gear 32. Its large crank 32, 33, or 34, is resting on a pivot, which is formed eccentrically and therefore forms a small crank 36. The base 37 of the eccentric rests firmly on the floor.

If the eccentric itself would be stationary, the end point of the large crank 32 would, when turning, describe a circular arc. Now, however, the height deviation of the end point from a straight line is compensated by the simultaneous turning of the eccentric. For mechanical reasons, it is necessary that the eccentric move in a larger circular arc than the large crank, which again results in the simultaneous turning of the crank and the eccentric, however, in a fixed conversion ratio. The drive shaft of the eccentric is steered by the large crank, which again is driven in a linear fashion, parallel to the straight line formed by the end point.

As a result of the measures instituted in this invention, it is possible for a simulator with parallel crank gears to infinitely vary the distance of the y- and z-axes, respectively, from the center of gravity S of the turret 21. A computer is no longer necessary to do this.

Tests have shown that the greatest deviation from the actual value to the theoretical value of the entire rotating arm is so small that it can be neglected, since manufacturing and other tolerances are of the same order of magnitude. /8

Figure 5 illustrates some movement phases of the parallelogram system for the infinite variation of the distance of the y- and z-axes, respectively, from the center of gravity S of the turret.

Patent Claims

1. Simulator for obtaining movements in six degrees of freedom, especially for a vehicle freely movable in space, characterized by the fact that parallel crank gears, whose turning axes can be individually started or stopped, are connected to a test cabin in such a way that, at the most, one translational movement of the test cabin results, but that all other movements are rotational and the simulator program can be varied through changes in the gear conversion ratios. /9

2. A simulator in accordance with claim No. 1 characterized by the fact that to the two mutually vertical parallel crank gears (13, 14, 15, and 16, and 13, 22, 23, and 24) there is added a double crank gear (32) and/or a parallel double crank gear (33 and 34) for the execution of rotational movements in all six degrees of freedom.

3. A simulator in accordance with claims Nos. 1 and 2, characterized by the fact that for each degree of freedom a self-contained construction unit with its own drive is provided.

4. A simulator in accordance with one or more of the preceding claims Nos. 1 to 3, characterized by the fact that a large crank (32, 33, or 34, respectively) of a parallel double crank gear (33 and 34) and a small crank (36), formed as an eccentric, can turn simultaneously in a fixed gear conversion ratio.

5. A simulator in accordance with one or more of the claims Nos. 1 to 4, /10

characterized by the fact that the gear elements of the parallel crank gears (13, 14, 15, and 16, and 13, 22, 23, and 24) are infinitely variable in length.

6. A simulator in accordance with one or more of the claims Nos. 1 to 5, characterized by the fact that to the parallel crank gear (13, 14, 15, and 16) for the movement of the system in the z-axis, there is attached a freely projecting platform (19), for instance, an angular one.

7. A simulator in accordance with claim 6, characterized by the fact that the angular platform (19) is equipped with means (20) for the interchangeable attachment of turrets (21) of various sizes and forms of construction, or of other objects to be tested.

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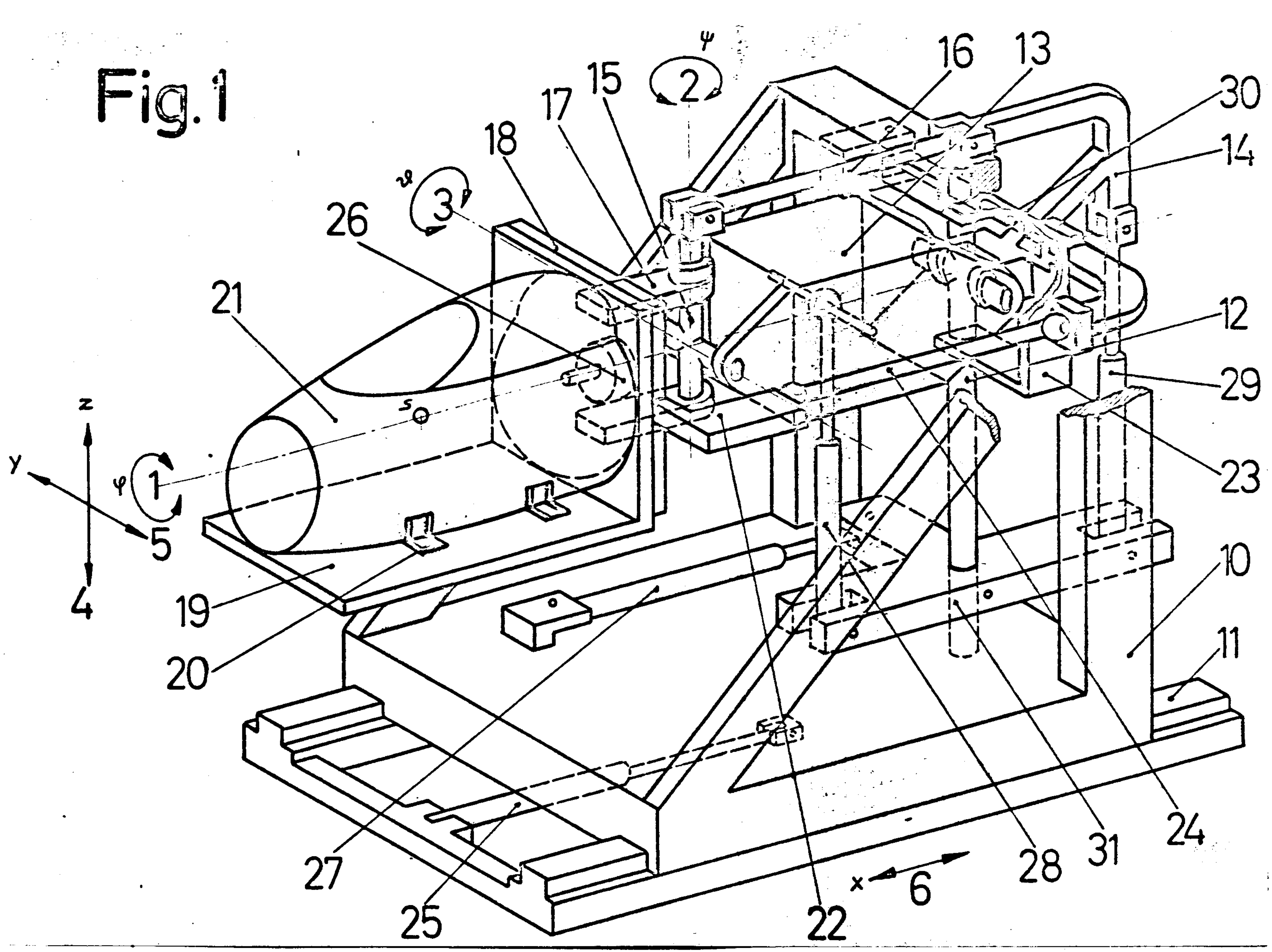
Fig.1



ψ
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ϑ
3
φ
1
z
y
4
5
x
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10
11
12
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Fig. 2

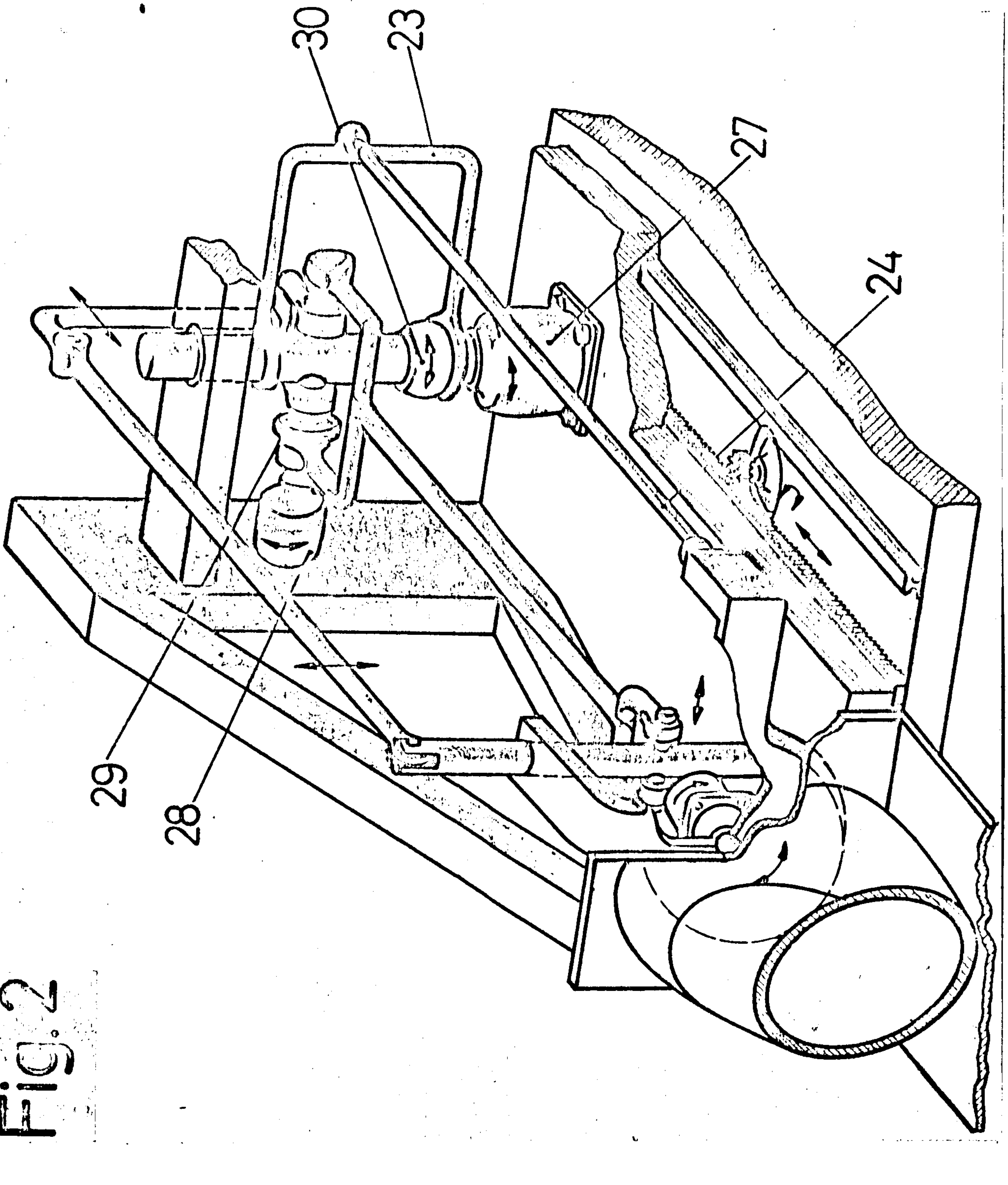
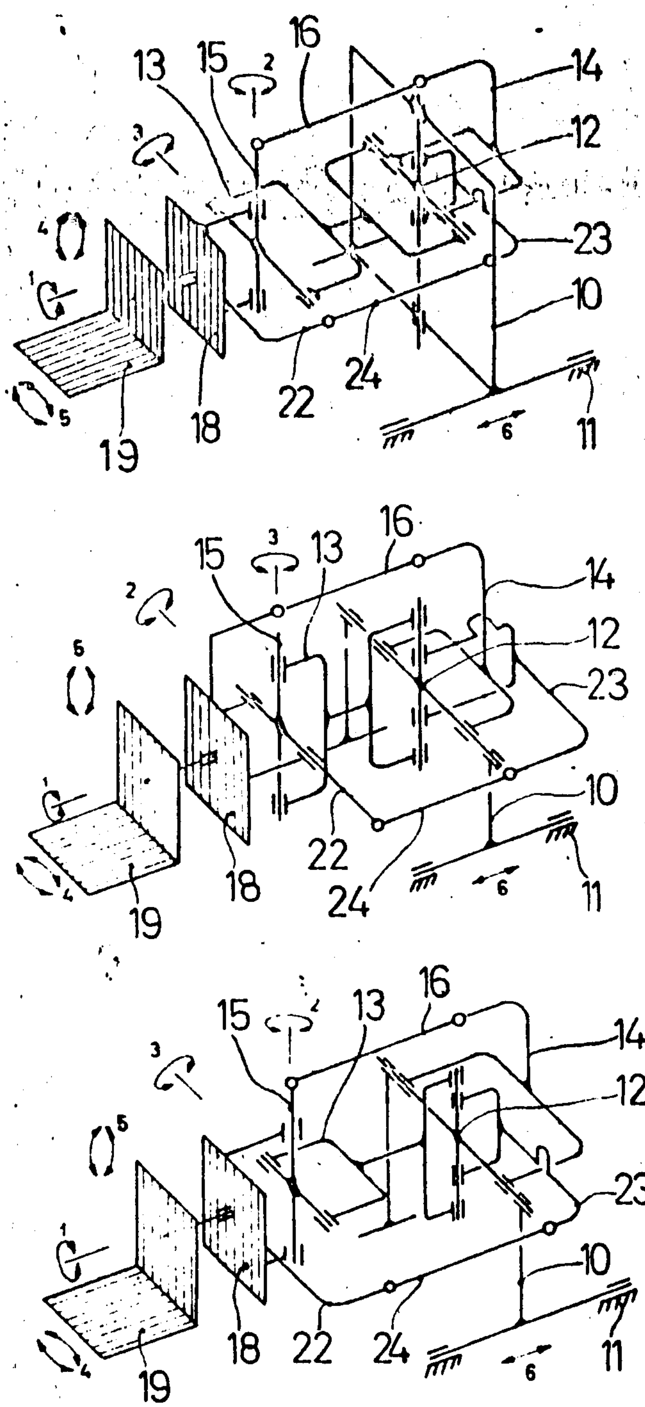


Fig. 3



Degree of freedom	Sequence of system movement	Movement
φ	1	rotational
ψ	2	rotational
ϑ	3	rotational
z	4	rotational rotational
y	5	rotational rotational
x	6	translational

φ	1
ϑ	2
ψ	3
y	4
z	5
x	6

φ	1
ψ	2
ϑ	3
y	4
z	5
x	6

FIGURE 3 Continued

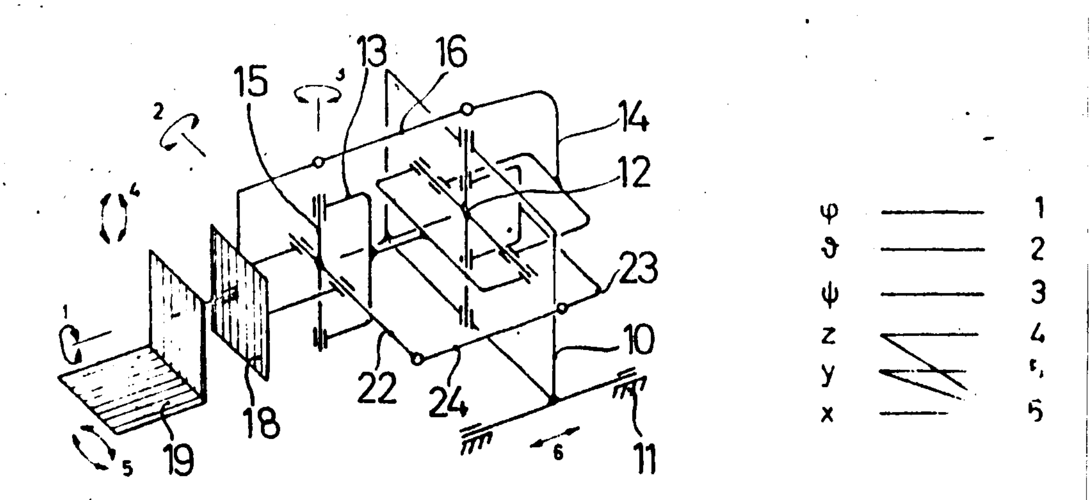
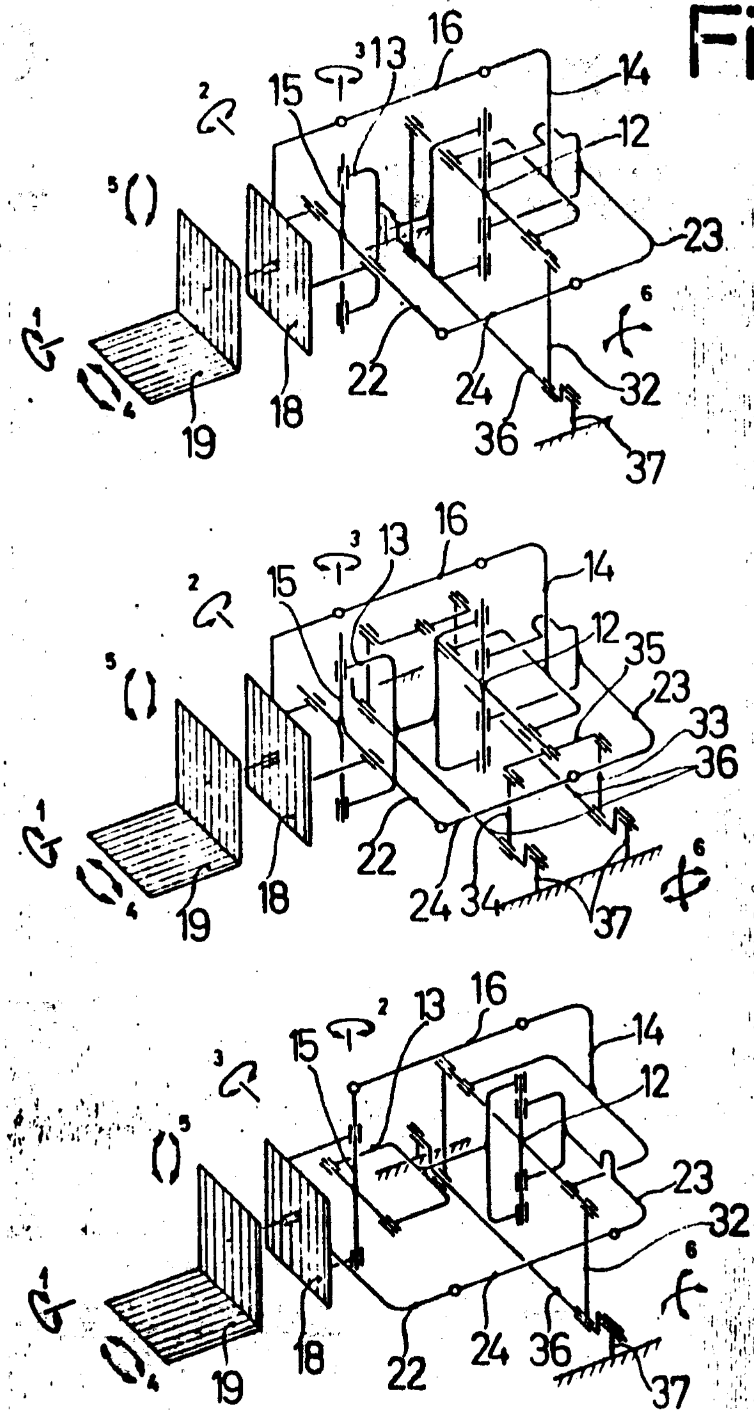


Fig.4



Degree of freedom	Sequence of system movement	Movement
φ	1	rotational
ϑ	2	rotational
ψ	3	rotational
y	4	{rotational rotational
z	5	{rotational rotational
x	6	{rotational rotational

Degree of freedom	Sequence of system movement	Movement
φ	1	rotational
ϑ	2	rotational
ψ	3	rotational
y	4	{rotational rotational
z	5	{rotational rotational
x	6	{rotational rotational

Degree of freedom	Sequence of system movement	Movement
φ	1	rotational
ψ	2	rotational
ϑ	3	rotational
y	4	{rotational rotational
z	5	{rotational rotational
x	6	{rotational rotational

FIGURE 4 Continued

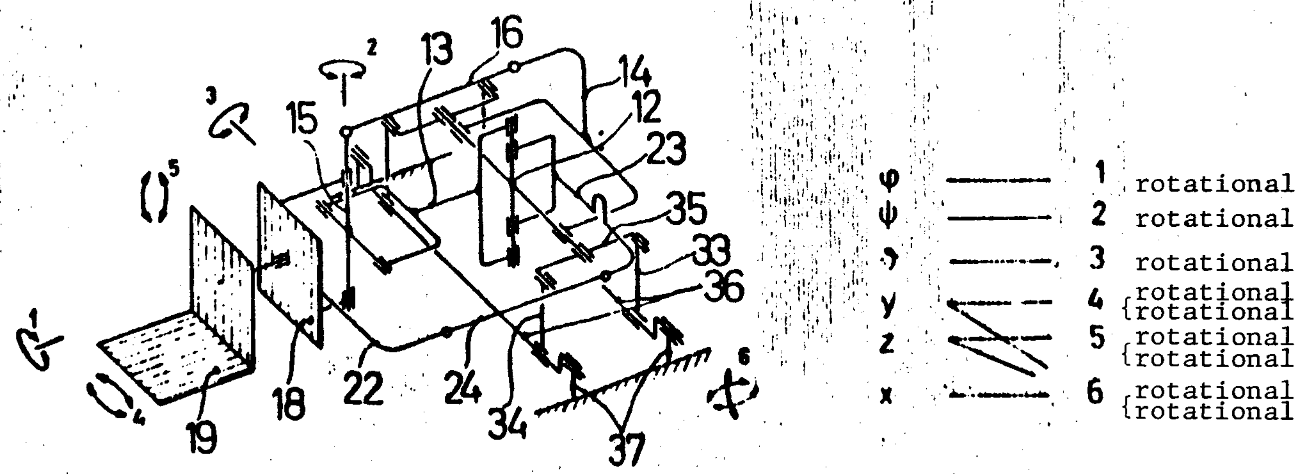


Fig.5

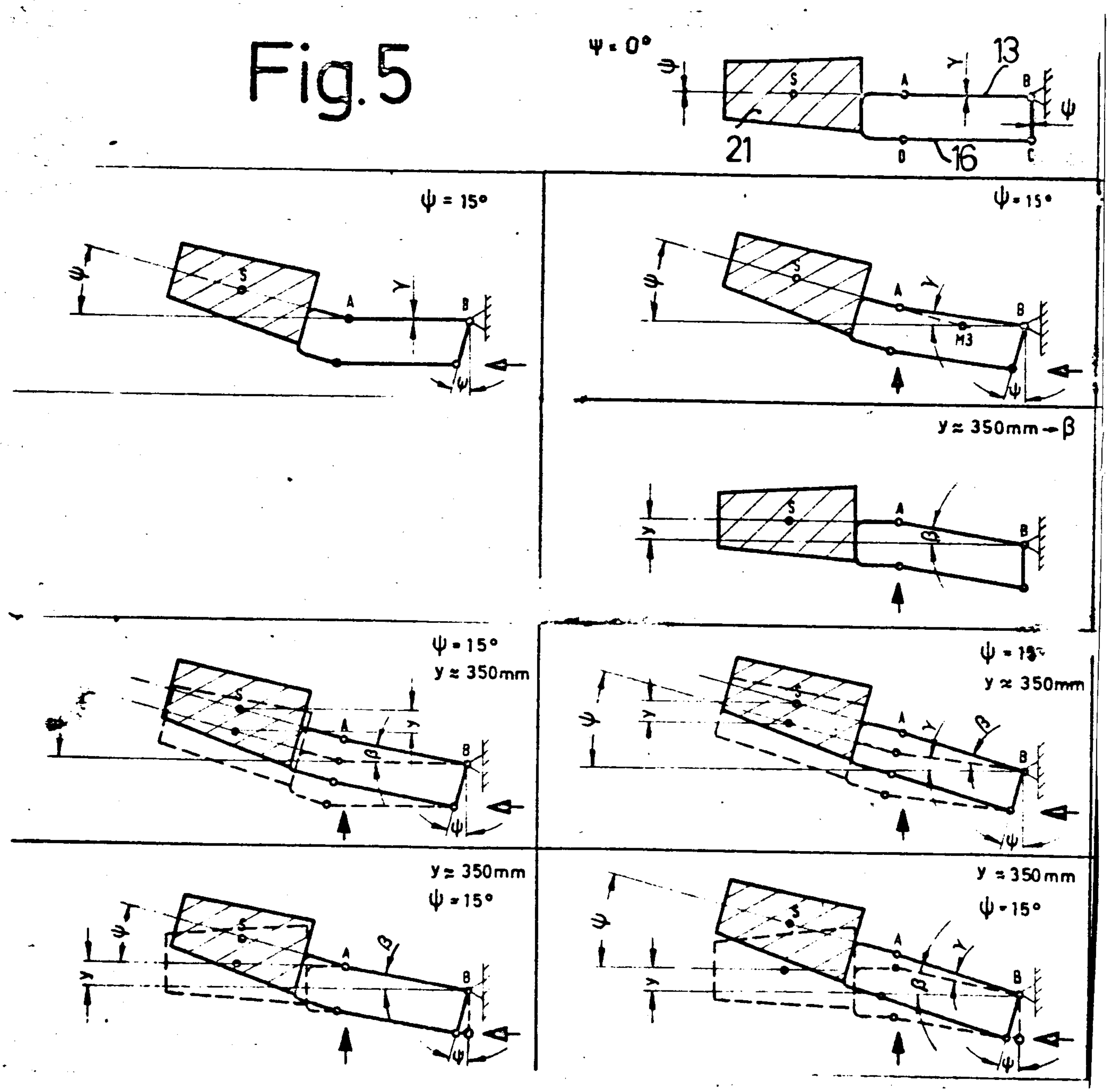


FIGURE 5 Continued